SEMIARID PRECIPITATION FREQUENCY STUDY

Update of *Technical Paper No. 40, Technical Paper No. 49* and *NOAA Atlas 2*

Twenty-third Progress Report
1 October 2002 through 31 December 2002

Hydrometeorological Design Studies Center
Hydrology Laboratory

Office of Hydrologic Development
U.S. National Weather Service
Silver Spring, Maryland

January 2003

DISCLAIMER

The data and information presented in this report should be considered as preliminary and are provided only to demonstrate current progress on the various technical tasks associated with this project. Values presented herein are NOT intended for any other use beyond the scope of this progress report. Anyone using any data or information presented in this report for any purpose other than for what it was intended does so at their own risk

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1. Introduction

The Hydrometeorological Design Studies Center (HDSC), Hydrology Laboratory, Office of Hydrologic Development, U.S. National Weather Service is updating its precipitation frequency estimates for the Semiarid Southwestern United States. Current precipitation frequency estimates for the Semiarid region are contained in *Technical Paper No. 40* "Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years" (Hershfield 1961), *Technical Paper No. 49* "Two- to ten-day precipitation for return periods of 2 to 100 years in the contiguous United States" (Miller et al 1964) and *NOAA Atlas 2* “Precipitation-Frequency Atlas of the Western United States.” The new study includes collecting data and performing quality control, compiling and formatting datasets for analyses, selecting applicable frequency distributions and fitting techniques, analyzing data, mapping and preparing reports and other documentation.

The study will determine annual all-season precipitation frequencies for durations from 5 minutes to 60 days, for return periods from 2 to 1000 years. The study will review and process all available rainfall data for the Semiarid study area and use accepted statistical methods. In particular, the Semiarid Study is the pilot study in which decisions regarding the methods and format are being made that will affect subsequent studies. The study results will be published as Volumes of *NOAA Atlas 14* on the internet using web pages with the additional ability to download digital files.

The Semiarid study will produce estimates for 4 states completely, Arizona, Nevada, New Mexico, and Utah, and southeastern California. Additional data from 7 bordering states and Mexico (Figure 1) are included for continuity across state borders. The core and border areas and regional groups for long duration (24-hour through 60-day) analyses are shown in Figure 1. Regional groups for short duration (60-minute through 12-hour) analyses are shown in Figure 2.

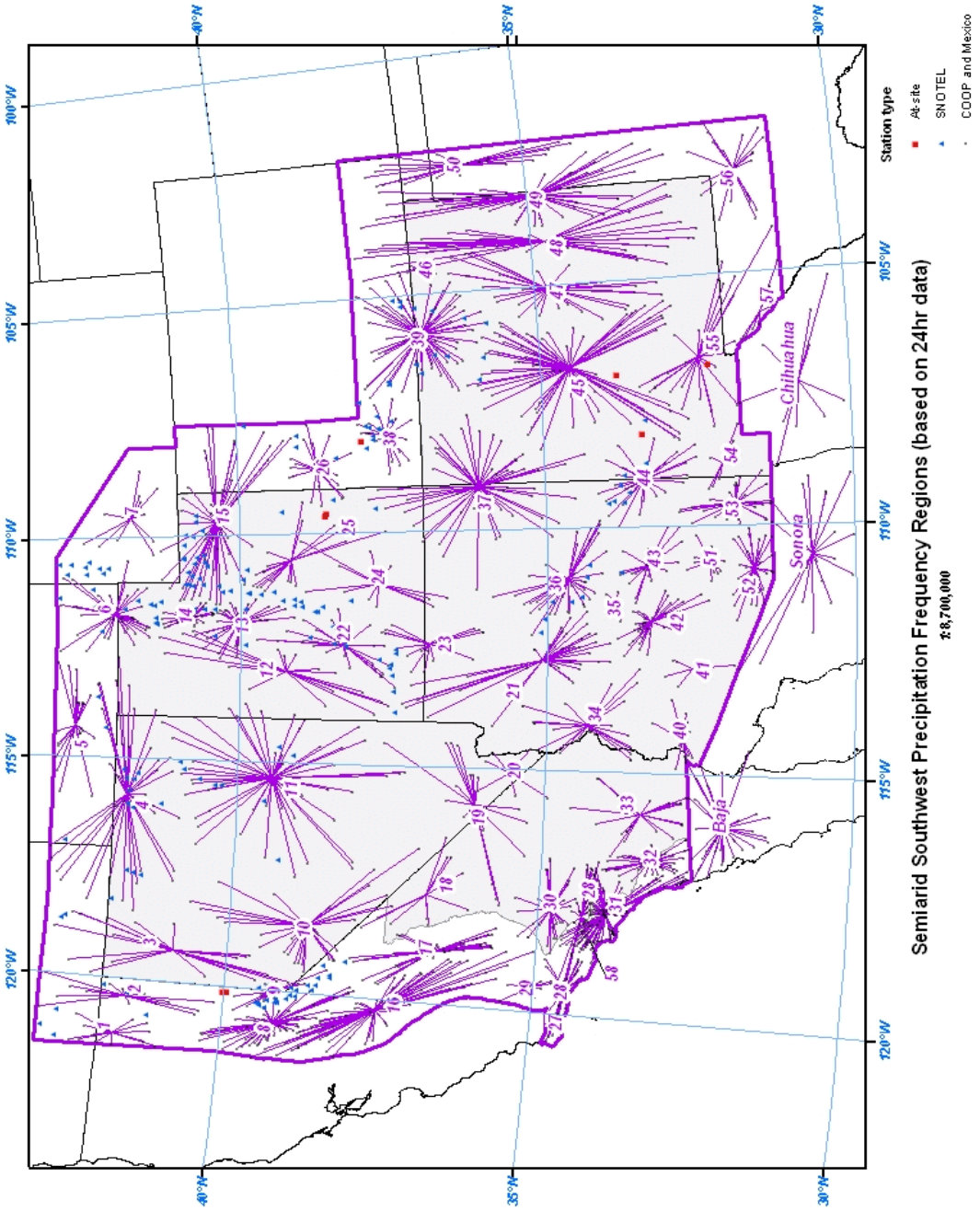


Figure 1. Semiarid Precipitation Frequency study area and new regional groups for 24-hour and longer duration values.

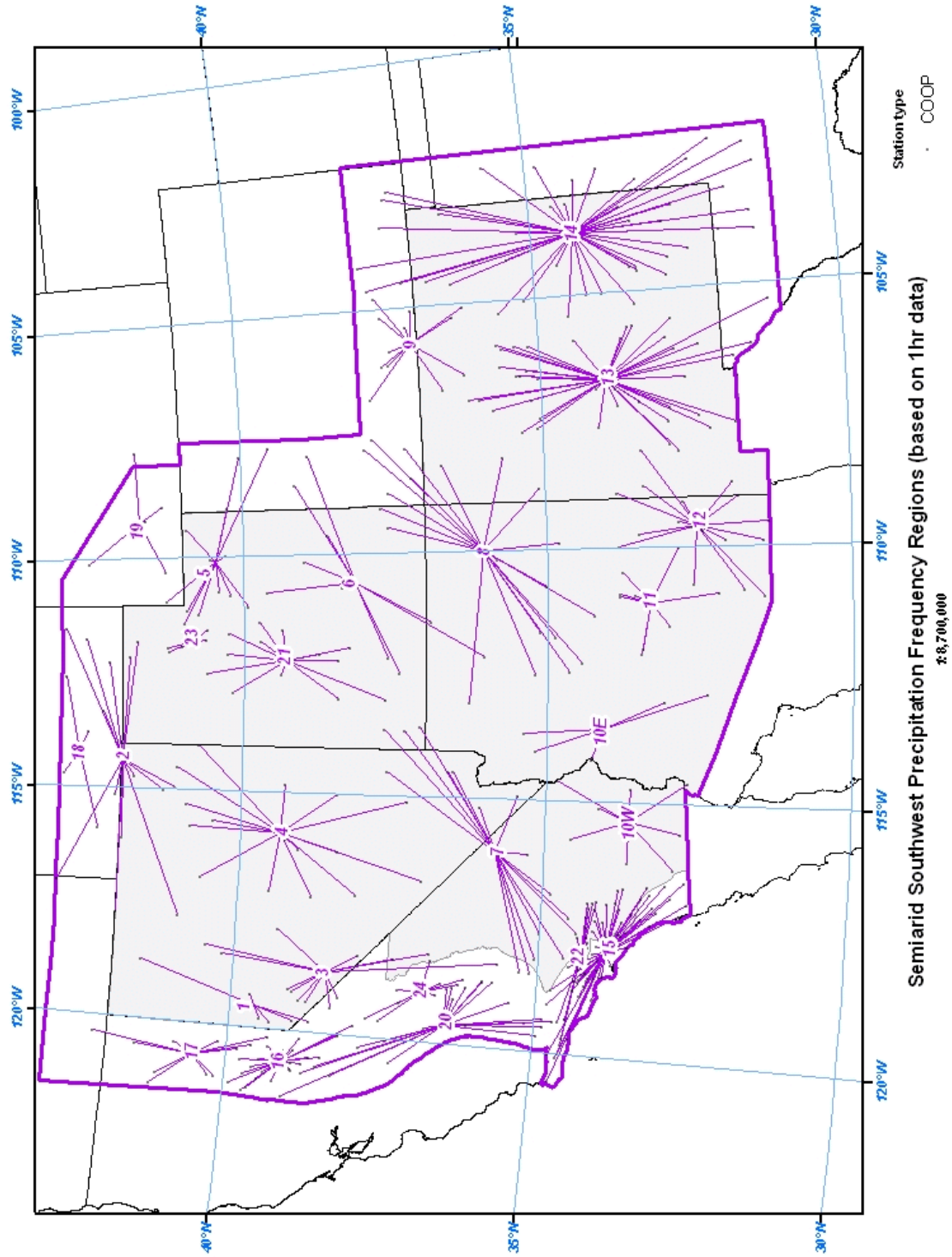


Figure 2. Semiarid Precipitation Frequency regional groups for 12-hour and shorter duration values.

2. Highlights

HDSC conducted a peer review of the spatially interpolated precipitation frequency estimates for the Semiarid Southwest United States from October 25 to December 6, 2002. We requested comments from roughly 84 people or agencies and received comments from 12, or about 14%. A document containing the comments and our responses to them was distributed on December 27, 2002. Additional information is provided in Section 4.1, Peer Review.

As a direct result of the peer review, additional n-minute stations were identified and added to the n-minute and hourly dataset in Riverside County, California. Additional hourly stations were also added to the Albuquerque, New Mexico area. Additional information is provided in Section 4.2, Data Addition.

Software was refined and automated to adjust quantiles for co-located hourly and daily data across all durations and frequencies. Software to compute and adjust confidence limits for co-located stations was also written. Software to carry quantile estimates of hourly stations out to 48-hours was completed. Additional information is provided in Section 4.3, Software Updates.

Seasonal information will be presented graphically as percentages of “exceedences” that occur in each month for a given region for 2-year, 10-year, 25-year, 50-year, and 100-year return frequencies. The software for the 1-hour and 24-hour durations has been written and preliminary graphs have been incorporated into the Precipitation Frequency Data Server. Additional information is provided in Section 4.4, Seasonal Graphs.

In addition to the 12-hour, 24-hour, and 4-day durations, it was decided that temporal distributions of extreme rainfall would be produced for the 6-hour duration. Additional information is provided in Section 4.5, Temporal Distributions.

The Spatial Climate Analysis Service (SCAS) delivered a 14-page interim report to HDSC on December 24, 2002 describing the production of the draft 1-hour and 24-hour “index flood” rainfall grids for the Semiarid Southwest study using PRISM. A minor change was made to the Cascade, Residual Add-back (CRAB) precipitation frequency grid derivation procedure to prevent multiple filtering as longer return frequencies are generated. Lastly, a final map/grid deliverable list was developed. Additional information is provided in Section 4.6, Spatial Interpolation.

In order to accommodate all of the Precipitation Frequency Data Server and geospatial files, the allocated disk space for the PFDS was increased. The PFDS output was also modified to include “seasonal exceedence graphs.” Additional information is provided in Section 4.7, Precipitation Frequency Data Server.

Progress towards the development of depth-area-duration (D-A-D) reduction relationships for areas from 10 to 400 square miles continues. The initial computer programming to quantify the spatial variation of storms used in the D-A-D analysis has been completed and tested successfully on two study areas. The second phase of the programming to perform the actual D-A-D curve fitting is nearly complete. Additional information is provided in Section 4.8, Depth Area Duration Study.

3. Status

3.1 Project Task List

The following checklist shows the components of each task and an estimate of the percent completed per task. Past status reports should also be referenced for additional information.

Semiarid study checklist [estimated percent complete]:

Data Collection, Formatting and Quality Control [100%]:

- Multi-day
- Daily
- Hourly
- 15-minute
- N-minute

Additional n-minute and hourly data were added in Riverside County, CA and near Albuquerque, NM. The datasets are complete.

L-Moment Analysis/Frequency Distribution for 5 minute to 60 days and 2 to 1000 years [100%]:

- Multi-day
- Daily
- Hourly
- 15-minute
- N-minute

L-moments were re-run on regions that were affected by the addition of new hourly data. Precipitation frequency estimates were also re-computed on all regions using the refined software to adjust stations for inconsistencies. These revised results are complete.

Spatial Interpolation [55%]

- Create mean annual maximum (a.k.a. “Index flood”) grids with PRISM for each duration (1-hr, 2-hr, 3-hr, 12-hr, 24-hr, 48-hr, 4-day, 7-day, 10-day, 20-day, 30-day, 45-day, 60-day)
- Apply a precipitation frequency map derivation procedure, known as the cascade residual add-back (CRAB) procedure to create a total of 162 grids. The same procedure will be used to create 162 upper and 162 lower bound precipitation frequency grids. (See Section 4.6 Spatial Interpolation for more details.)

- Apply study-wide conversion factor to the 60-minute precipitation frequency grids to calculate the n-minute (5-, 10-, 15-, and 30-minute) grids

Draft grids of spatially interpolated mean 1-hour and 24-hour annual maxima values (a.k.a. “index flood”) were peer reviewed. CRAB software was modified to reduce multiple filtering.

Peer Reviews [95%]

- Lead review of point precipitation frequency estimates
- Lead review of spatial interpolation grids

The review of spatially-interpolated precipitation frequency estimates and “index flood” grids is complete. HDSC responded to reviewer comments and made appropriate changes based on their recommendations.

Data Trend Analysis [95%]

- Analyze linear trends in annual maxima and variance over time
- Analyze shift in means of annual maxima between two time periods (i.e., test the equality of 2 population distribution means)

The trend and shift analyses of 1-day annual maximum series are complete pending a peer review of results.

Temporal Distributions of Extreme Rainfall [80%]

- Assemble hourly data by quartile of greatest precipitation amount and convert to cumulative rainfall amounts for each region
- Sort, average, and plot time distribution of hourly maximum events for different climatological regions and seasons

Temporal distributions for 12- and 24-hour durations are complete. Work has begun on computing the 4-day and 6-hour durations. Documentation has been written.

Deliverables [55%]

- Prepare data for web delivery
- Prepare documentation for web delivery
- Write hard copy of Final Report
- Publish hard copy of Final Report

A detailed outline of the final documentation is complete. Some documentation has been written. The Precipitation Data Frequency Server (PFDS) has been modified to include seasonal graphs.

Spatial Relations (Depth-Area-Duration Study) [60%]

- Obtain hourly data from dense-area reporting networks
- QC and format data from dense networks
- Compute maximum and average annual areal depth for each duration from stations for each network
- Compute ratio of maximum to average depth for all durations and

networks and plot
- Prepare curves of best fit (depth-area curves) for each duration and network
- Combine all stations from all study areas to compute the ratio of maximum to average depth for all durations and networks and plot
- Examine differences in individual D-A-D curve plots for durations and study areas compared to those for combined study area data plots

D-A-D reductions for areas from 10 to 400 square miles are being updated for the entire United States and will be presented in a separate volume of NOAA Atlas 14.

4. Progress in this Reporting Period

4.1 Peer Review.

HDSC conducted a peer review of the spatially interpolated precipitation frequency estimates for the Semiarid Southwest United States from October 25 through December 6, 2002. We requested comments from roughly 84 people or agencies and received comments from 12, or about 14%. We interpreted that as satisfaction with the results. The responses were comprehensive and very helpful. After parsing the responses, there were 36 unique comments. In order to allow all of the reviewers the opportunity to see what other reviewers commented on, we prepared a document containing the parsed comments and our responses to them. The wording of the comments was unchanged to make sure the meaning was not misconstrued and so reviewers could identify their comments. We have addressed most of the comments by adding data, showing "index flood" vs. square-root of mean annual precipitation relationships and describing our process in more detail.

4.2 Data Addition

As a direct result of the peer review process, additional data are being added to the n-minute and hourly datasets in Riverside County, California due to the spatial complexity of the area. The data of 8 existing stations were supplemented by new Riverside data in hourly region 15 (see Figure 2). Initially, 11 new stations have been added to region 15 and 7 new stations to region 10W. Preliminary results show that, with the addition of these data, 100-year quantile estimates in Riverside County will change up to 15%, generally decreasing.

Four new hourly stations with at least 15 years of available data were added to hourly region 13 near Albuquerque, New Mexico. With the addition of these 4 stations, the 100-year quantile estimates increased less than 1% for all durations.

4.3 Software Updates

Internal consistency software was refined to include all durations and all return frequencies. When internal consistency adjustments are made in the quantiles for one return frequency, it is necessary to adjust all frequencies to maintain realistic results (i.e., so that 50-year estimates are not greater than 100-year estimates). This is particularly true at shorter return frequencies because ratios of small values can be large, leading to large adjustments. Software to carry quantile estimates of hourly stations out to 48-hours was also completed.

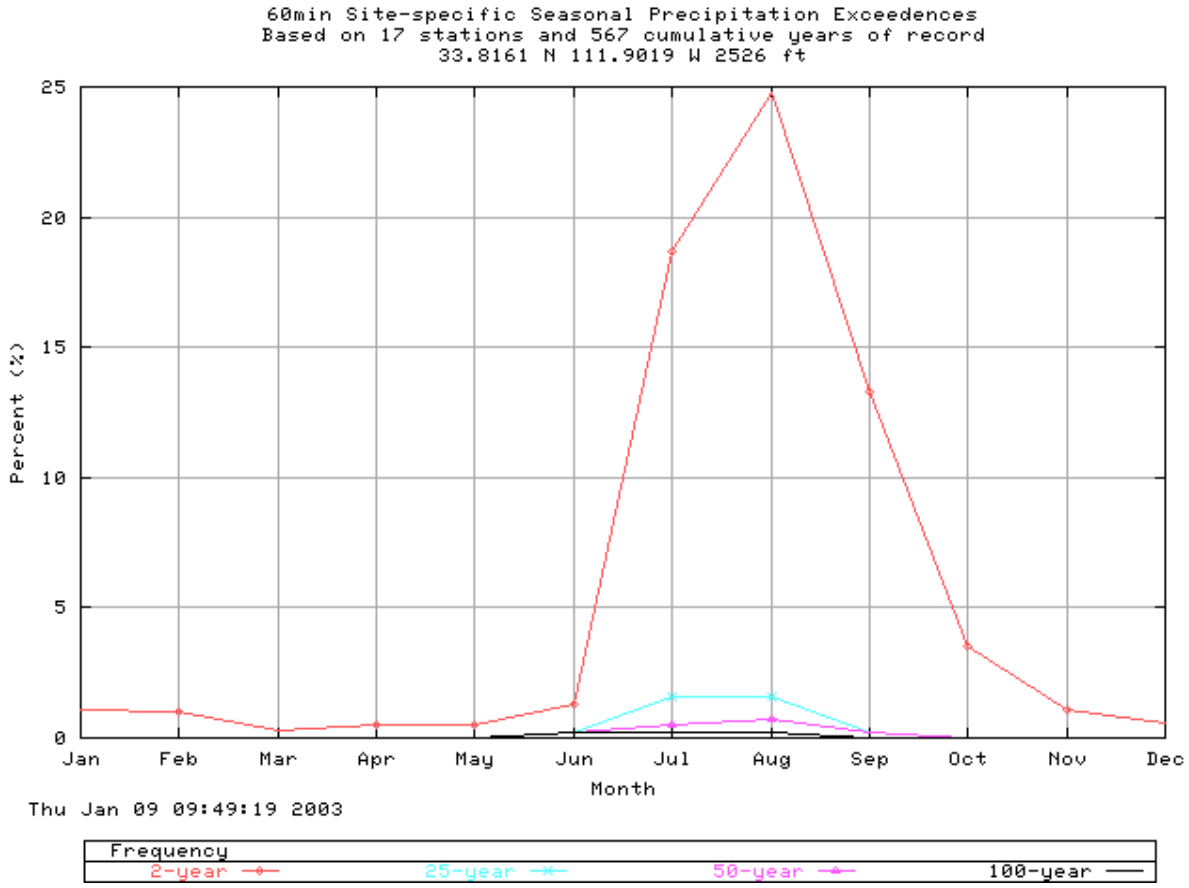
Software was created to generate a complete list of co-located hourly and daily stations with their assigned regions and run existing adjustment software on all regions at once with minimal manual input. This provides a more efficient and less error-prone mechanism for completing the precipitation frequency analysis for a given study area. In addition, software to compute and adjust confidence limits for co-located stations was written.

4.4 Seasonal Graphs

Seasonal information will be presented graphically as percentages of "exceedences" that occur in each month for a given region. "Exceedences" are events that exceed corresponding 2-year, 10-year, 25-year, 50-year, and 100-year precipitation frequency estimates at a given station and duration. The percentage is derived from the total number of cumulative years for all stations in a given region. Theoretically, 50% of the events should exceed the 2-year estimates, 4% should exceed the 25-year estimates, 2% should exceed the 50-year estimates and only 1% should exceed the 100-year estimates.

Exceedence graphs will be presented for the 1-hour, 24-hour, 48-hour and 10-day durations. Figure 3 is an example of an exceedence graph where extreme precipitation occurs primarily in July, August and September. The software for the 1-hour and 24-hour durations has been written and preliminary graphs have been incorporated into the Precipitation Frequency Data Server. Work is nearly complete for the 48-hour and 10-day durations.

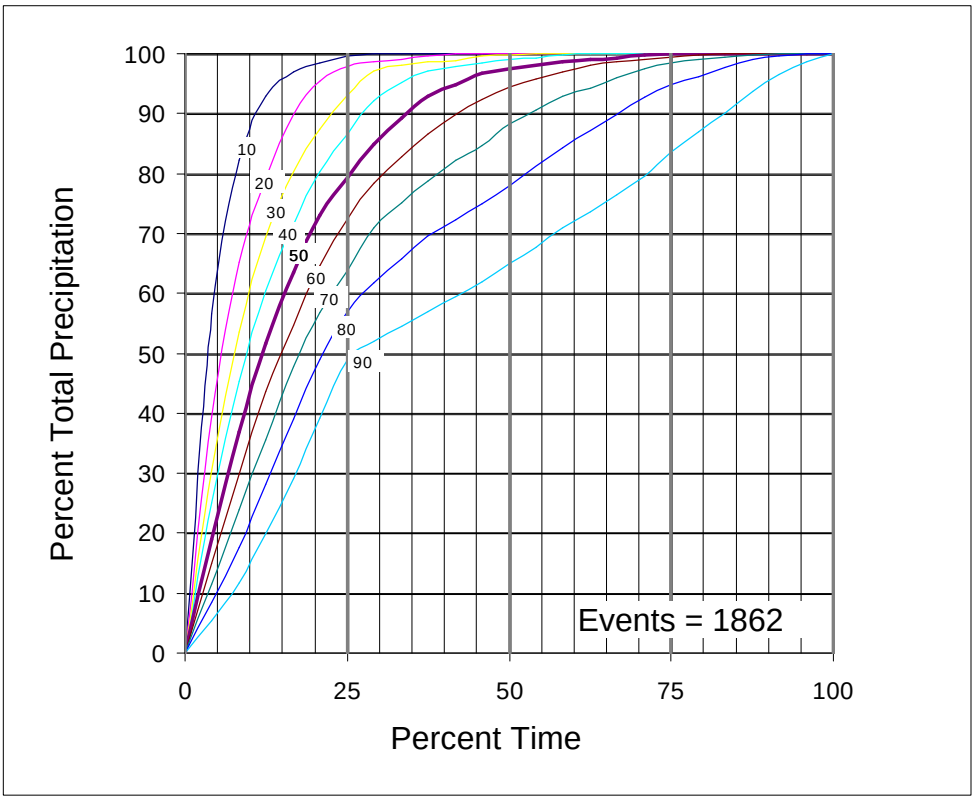
Figure 3. 60-minute exceedence graph for Carefree, Arizona (02-1282).



4.5 Temporal Distributions

In addition to the 12-hour, 24-hour, and 4-day durations, it was decided that temporal distributions of extreme rainfall would be produced for the 6-hour duration. Distributions are grouped according to the quartile of time in which the most rain fell. All quartiles from each duration, 6-hour, 12-hour, 24-hour and 96-hour will be presented in the final document. In addition, a single plot combining all four quartiles into a single distribution will be presented for each duration. Figure 4 shows an example of a temporal distribution for 96-hour duration events in which 1st quartile precipitation dominated. The results will be peer reviewed in January.

Figure 4. Example of 1st quartile temporal distribution of 96-hour duration events.



4.6 Spatial Interpolation

The Spatial Climate Analysis Service (SCAS) at Oregon State University delivered a 14-page interim report to HDSC on December 24, 2002. The report describes the work performed to produce the draft 1-hour and 24-hour "index flood" rainfall grids for the Semiarid Southwest study using the PRISM model (Parameter-elevation Regressions on Independent Slopes Model). These grids were subsequently contoured and mapped by HDSC for the spatial review (see Section 4.1, Peer Review for more details).

A minor change, motivated by review comments, was made to the Cascade, Residual Add-back (CRAB) precipitation frequency grid derivation procedure (see CRAB description in 22nd Progress Report, Section 4.7). Instead of using a final, slightly filtered grid as the predictor for the subsequent grid, the CRAB procedure now maintains and uses unfiltered grids for its predictor grids throughout the process. The final grids for each precipitation frequency estimate are still slightly filtered, but because

filtering is not done on the predictor grid, a greater level of spatial detail is maintained and portrayed in the resulting grids/maps. This minor change helped mitigate several of the observations made by reviewers during the spatial review.

Lastly, a final map/grid deliverable list was developed (see Table 1). All durations and return frequencies will have ArcInfo ASCII grids and ESRI shapefiles of isohyets. Initially, a subset of durations and return frequencies will have state-specific printable cartographic maps in PDF format with the remaining durations to be produced as time permits in the future (indicated in table by asterisks).

Table 1. List of all map/grid deliverables.

	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr	1000-yr
5-min	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
10-min	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
15-min	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
30-min	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
60-min	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	G, S, SM*	G, S, SM*	G, S, SM*
120-min	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
3-hr	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
6-hr	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	G, S, SM*	G, S, SM*	G, S, SM*
12-hr	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
24-hr	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	G, S, SM*	G, S, SM*	G, S, SM*
48-hr	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
4-day	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
7-day	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
10-day	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	G, S, SM*	G, S, SM*	G, S, SM*
20-day	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
30-day	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
45-day	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*	G, S, SM*
60-day	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	**G, S, SM**	G, S, SM*	G, S, SM*	G, S, SM*

G = ArcInfo ASCII grid
S = ESRI shapefile of isohyets
SM = State-specific printable cartographic map (PDF format)
SM* = State-specific printable cartographic map (PDF format) as time permits

4.7 Precipitation Frequency Data Server.

In order to accommodate all of the PFDS and GIS compatible files, the allocated disk space for the PFDS was increased to 30 gigabytes. Our calculations suggest that this will be ample disk space to accommodate all of our current precipitation frequency projects.

The PFDS output was also modified to include “seasonal exceedence graphs” (see Section 4.4, Seasonal Graphs). The total number of stations and the total number of cumulative years used in the calculations are provided in the graph title.

4.8 Spatial Relations (Depth-Area-Duration Study)

Progress towards the development of depth-area-duration (D-A-D) reduction relationships for area sizes of 10 to 400 square miles continues. The initial computer programming to quantify the spatial variation of storms used in the D-A-D analysis has been written, tested successfully, and performed on two study areas. The second phase of the programming to perform the actual D-A-D curve fitting is nearly complete and will be tested in January on two study areas. There has been no change in the D-A-D study areas that will be used to develop the final D-A-D curves (see previous progress report). Currently, there are 12 study areas scattered throughout the conterminous United States that have been quality controlled. Three other study areas may be added once the D-A-D curves are developed for the existing study areas. These three study areas will be used if it is determined that a single curve for the entire U.S. is insufficient and separate curves need to be developed.

5. Issues

5.1 Personnel Change

As of December 5, 2002, Eloisa Raynault resigned from HDSC. Eloisa was a civil engineer who was the project lead for the Ohio River Basin and Surrounding States Precipitation Frequency Study. A replacement will not be hired due to budget constraints. Debbie Todd will take on the responsibility of project lead for the Ohio River Basin Study. Unfortunately, Eloisa's departure has forced a delay in project schedules.

5.2 AFMA Meeting

Geoff Bonnin, Tye Parzybok and Debbie Todd attended the Arizona Floodplain Management Association meeting in Rio Rico, Arizona on November 7th, 2002. Geoff presented an overview of HDSC's work on the update to NOAA Atlas 2. Debbie and Tye presented a detailed technical discussion on the causes of differences between NOAA Atlas 2 and NOAA Atlas 14 for the state of Arizona.

5.3 AMS Annual Meeting

HDSC is presenting four papers/posters at the 83rd American Meteorological Society Annual Meeting in February of 2003. The papers include *Updating NOAA/NWS Rainfall Frequency Atlases*, which will give an overview of our approach, *Updated Precipitation Frequencies for the Semiarid Southwest United States*, which will present selected results from the Semiarid study, *Updated Precipitation Frequencies for the Ohio River Basin and Surrounding States*, which will present selected results from the Ohio study, and *NOAA/NWS Precipitation Frequency Data Server*, which will present the PFDS in detail.

6. Projected Schedule.

The following list provides a tentative schedule with completion dates. Brief descriptions of tasks being worked on next quarter are also included in this section.

Data Collection and Quality Control [complete]
L-Moment Analysis/Frequency Distribution [complete]
Temporal Distributions of Extreme Rainfall [January 2003]
Peer review of point estimates [complete]
Trend Analysis [complete]
Spatial Interpolation [February 2003]
Precipitation Frequency Maps [March 2003]
Final Report [April 2003]
Web Publication [April 2003]
Spatial Relations (Depth Area Duration Studies) [February 2003]

6.1 L-Moment Analysis/Frequency Distribution.

With the addition of new data, a final run of L-moment statistical analyses and internal consistency adjustments will be made early next quarter. Also, confidence intervals associated with each precipitation frequency estimate will be computed and adjusted for internal consistency. New partial duration series will be generated to calculate the final conversion factors with annual maximum series in the next quarter.

6.2 Trend Analysis and Seasonal Analysis

A peer review of the trend and shift statistical test results will be conducted. Seasonal exceedence graphs will be created for 48-hour and 10-day durations and incorporated into the PFDS. Both the trend and seasonal analyses will be completed in the next quarter.

6.3 Temporal Distributions of Extreme Rainfall

Temporal distributions for extreme rainfall of 6-hour duration will be completed and all results will be peer reviewed during the next quarter.

6.4 Spatial Interpolation

During an upcoming meeting with SCAS, adjustments to the PRISM process will be made based on spatial review results. Final “index flood” grids will be produced for all durations. HDSC will perform the CRAB procedure on the “index flood” grids and generate final map and shapefile deliverables during the next quarter.

6.6 Documentation

Final documentation will be written and the final version of the PFDS will be constructed during the next quarter.

6.7 Spatial Relations (Depth-Area-Duration Study)

Software development for the D-A-D computations will be completed in the next quarter and the computations will be performed for 12 study areas.

References

Frederick, R.H., V.A. Myers and E.P. Auciello, 1977: Five- to 60-minute precipitation frequency for the eastern and central United States, NOAA Technical Memo. NWS HYDRO-35, Silver Spring, MD, 36 pp.

Hershfield, D.M., 1961: Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years, *Weather Bureau Technical Paper No. 40*, U.S. Weather Bureau. Washington, D.C., 115 pp.

Hosking, J.R.M. and J.R. Wallis, 1997: *Regional frequency analysis, an approach based on L-moments*, Cambridge University Press, 224 pp.

Huff, F. A., 1990: Time Distributions of Heavy Rainstorms in Illinois, *Illinois State Water Survey*, Champaign, 173, 17pp.

Lin, B. and L.T. Julian, 2001: Trend and shift statistics on annual maximum precipitation in the Ohio River Basin over the last century. Symposium on Precipitation Extremes: Prediction, Impacts, and Responses, 81st AMS annual meeting. Albuquerque, New Mexico.

Miller, J.F., 1964: Two- to ten-day precipitation for return periods of 2 to 100 years in the contiguous United States, *Technical Paper No. 49*, U.S. Weather Bureau and U.S. Department of Agriculture, 29 pp.

Miller, J.F., R.H. Frederick and R.J. Tracy, 1973: Precipitation-frequency atlas of the western United States, *NOAA Atlas 2*, 11 vols., National Weather Service, Silver Spring, MD.